

U.S. Air Force

Integrity - Service - Excellence



U.S. AIR FORCE

Digital Engineering Applications to Developmental Test & Evaluation

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Systems Engineering Conference

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Introduction

- There is a Digital Engineering revolution sweeping the Aerospace and Defense Industry
- The DoD is focusing on Digital Engineering applications to Systems Engineering in support of Acquisition and Sustainment
- Most OEMs have ongoing internal digital thread model-based engineering activities
- Industry related groups like the AIAA, NDIA, ITEA, etc., are focusing symposia on topics related to Digital Engineering

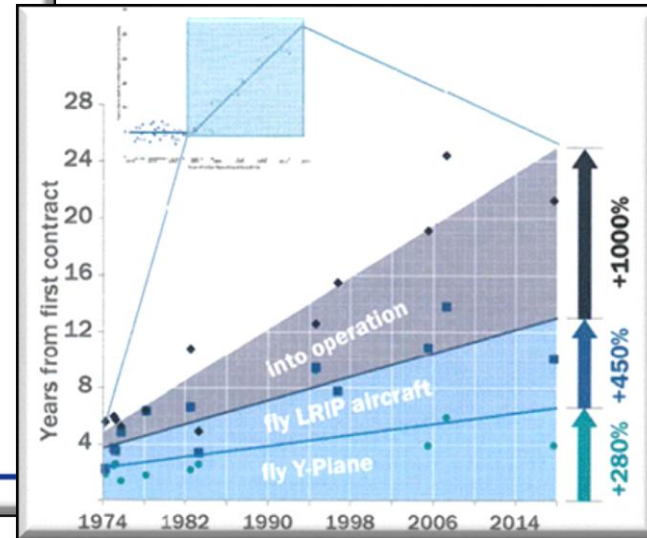
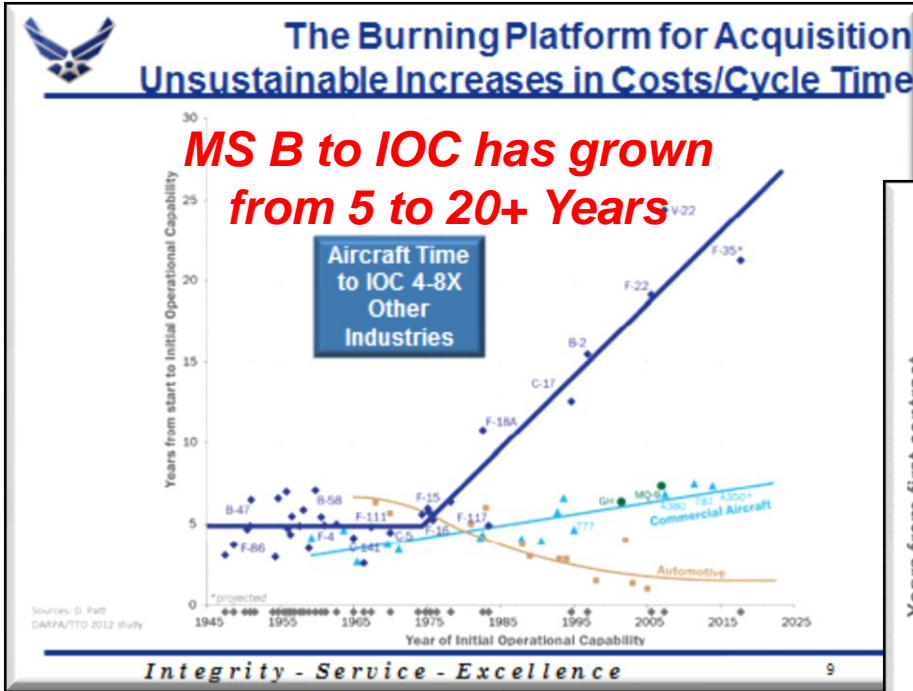


How does the T&E community fit in and how can we leverage the Digital Engineering environment to increase the value of T&E to acquisition and sustainment ?



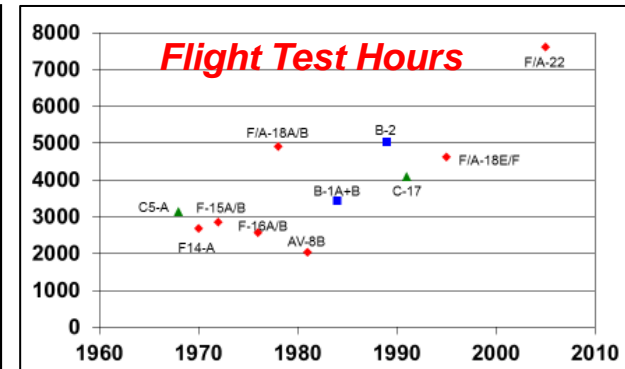
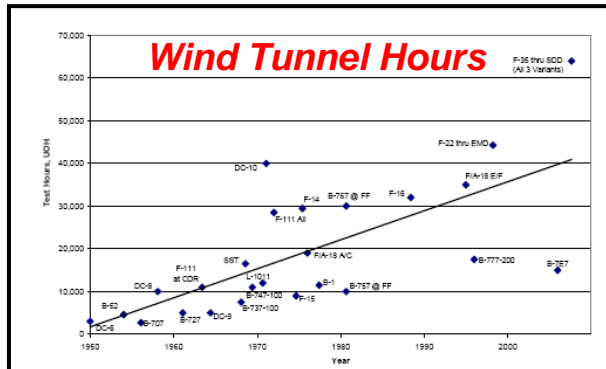
Why T&E Needs to Change

*T&E isn't the only cause,
But overlays 85% of the cycle time . . .*



INSANITY:
doing the same thing over and
over again and expecting
different results.

~ Albert Einstein





Leveraging Multiple Activities to Advance Digital Engineering within DoD



Infusion in Policy and Guidance

DoDI 5000.02, Enclosure 3, Section 9: Modeling and Simulation

Defense Acquisition Guidebook Chapter 4

DoD Digital Engineering Fundamental

Defense Acquisition Guidebook Chapter 4

<http://www.acq.osd.mil/se/pg/guidance.html>

DoD Initiatives

Digital Engineering Working Group

DoD Digital Engineering Working Group

ERS: Adapting to changing requirements

SERC: Model Centric Collaborative Environment

DSM Taxonomy: Foundation for defining categories of data across acquisition

HPCMP CREATE: Physics Based Modeling

Other Partnerships



DMDII
DIGITAL MANUFACTURING AND DESIGN INNOVATION INSTITUTE

Additive Manufacturing

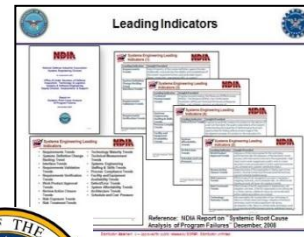
IAWG

Inter-Agency Working Group on the Engineering of Complex Systems



NASA: Sounding Rocket Program

NDIA: Essential Elements of the System Model



USAF Own the Technical Baseline

Digital Thread/Digital Twin

Advancing the state of practice for Digital Engineering within DoD



OSD Digital Engineering Definitions

(Defense Acquisition Guide Glossary)

- **Digital Engineering**: An integrated digital approach that uses authoritative sources of systems' data and models as a continuum across disciplines to support lifecycle activities from concept through disposal.
- **Digital Engineering Ecosystem**: The interconnected infrastructure, environment, and methodology (process, methods, and tools) used to store, access, analyze, and visualize evolving systems' data and models to address the needs of the stakeholders.
- **Digital Artifact**: The artifacts produced within, or generated from, the digital engineering ecosystem. These artifacts provide data for alternative views to visualize, communicate, and deliver data, information, and knowledge to stakeholders.
- **Technical Coherency**: The logical traceability of the evolution of a system's data and models, decisions, and solutions throughout the lifecycle.

**Digital Engineering Tenet - The Models are the Master
Moving from Paper to Digits**



Paradigm Shift – Keys to Success

1. Policy changes – government as virtual monopsony

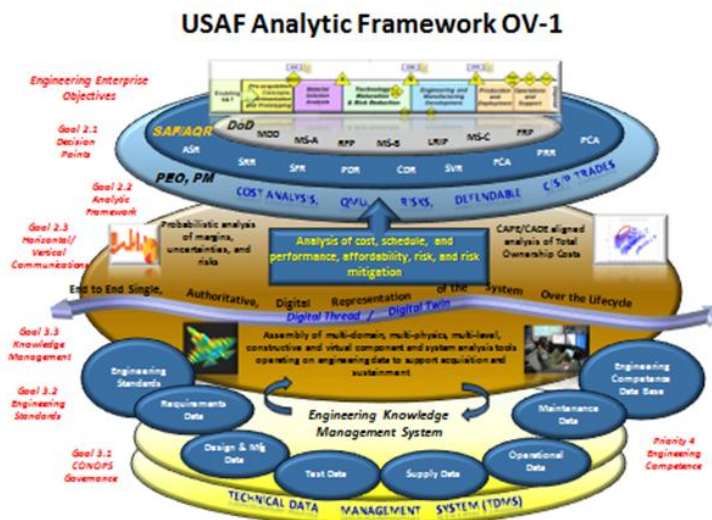
- OSD BBP 3.0 Organic Engineering Capability
- SAF/AQ Own the Tech Baseline/Bend the Cost Curve
- AF Engineering Enterprise Strategic Plan – policies, tools, structure, skills

2. Analytic Framework

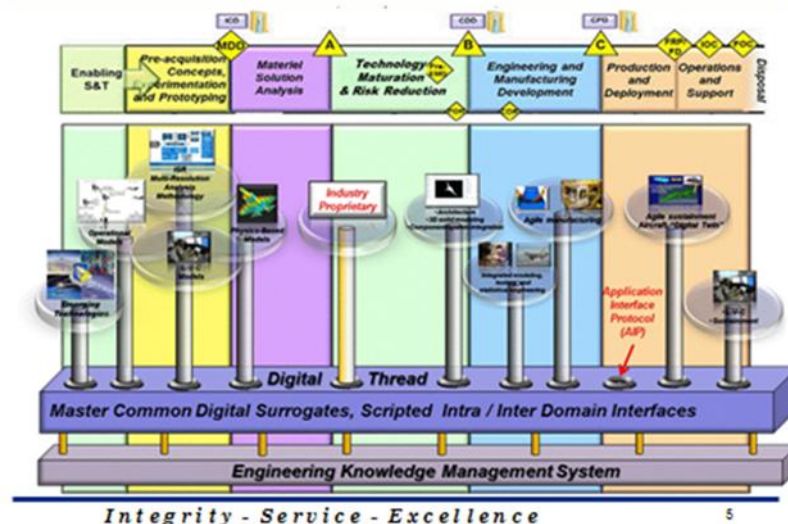
- Digital Thread/Digital Twin –life cycle digital engineering
- Knowledge Management

3. High fidelity, multi-level, multi-physics modeling tools

- CREATE, ICME, Others



The Air Force Digital Thread/Digital Twin





The AF Digital Thread / Digital Twin

The Analytical Framework

Digital System Model - A digital representation of a weapon system, generated by all stakeholders, that integrates the authoritative data, information, algorithms, and systems engineering processes which define all aspects of the system for the specific activities throughout the system lifecycle.

Digital Thread - An extensible, configurable and Agency enterprise-level analytical framework that seamlessly expedites the controlled interplay of authoritative data, information, and knowledge in the enterprise data-information-knowledge systems, based on the Digital System Model template, to inform decision makers throughout a system's life cycle by providing the capability to access, integrate and transform disparate data into actionable information.

Digital Twin - An integrated multiphysics, multiscale, probabilistic simulation of an as-built system, enabled by Digital Thread, that uses the best available models, sensor information, and input data to mirror and predict activities/performance over the life of its corresponding physical twin.

Common interest in a physics-based, multi-discipline, multi-physics, cross-domain, model of a system's capabilities and performance



Tenets of the Digital Thread/Digital Twin

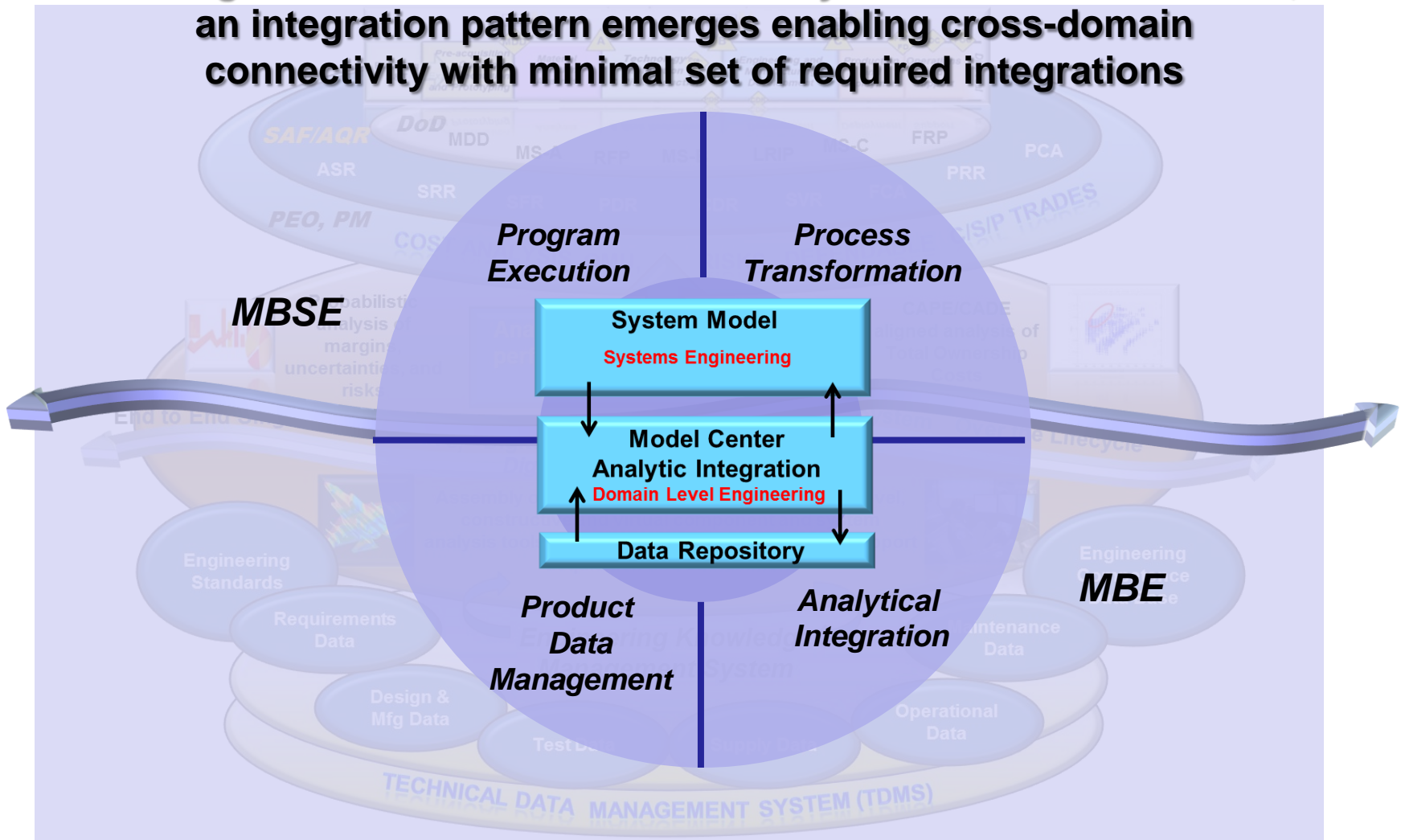
- **Access to and ability to exercise data to enable the government to understand performance and technical risk, i.e., “Own the Technical Baseline”**
- **End-to-end system model – ability to transfer knowledge upstream and downstream and from program to program**
- **Single, authoritative digital representation of the system over the life cycle**
- **Application of reduced order response surfaces and probabilistic analyses to quantify margins and uncertainties in cost and performance**
- **Preserve meta-data on decision processes and outcomes**



Digital Thread / Digital Twin

The System Architecture Model

Viewing the DT/DTw as the Hub of the System Architecture Model, an integration pattern emerges enabling cross-domain connectivity with minimal set of required integrations





Decision Analytics

INPUT

- Quantified assessment of the state of the SUD* relative to KPP/KSAs
- Probabilistic assessment of risk and costs
- COA scenarios

- SUD requirements
- Updated authoritative digital surrogate for system in reduced order model format

- Engineering standards
- Program requirements
- Digital drawings
- Technical data
- Test data

Prescriptive Analytics:

Used to understand what should be done or to recommend the best course of action for any pre-specified outcome

Predictive Analytics:

Probabilistic analysis of system state, used to forecast what might happen or could be accomplished.

Descriptive Analytics:

Application of Model Based Engineering analysis tools to transform technical data into useful technical information. Used for data interpretation, evaluation of system/subsystem capabilities wrt requirements

OUTPUT

- Prognosis of future states
- Comparative analysis of COAs
- Recommended COA

- Quantified margins and uncertainties
- Risk assessment
- Probable cost assessment

- Analysis of alternatives
- Evaluation of SUD
- Technical reports/briefings
- Updated authoritative digital surrogate for the system/subsystems

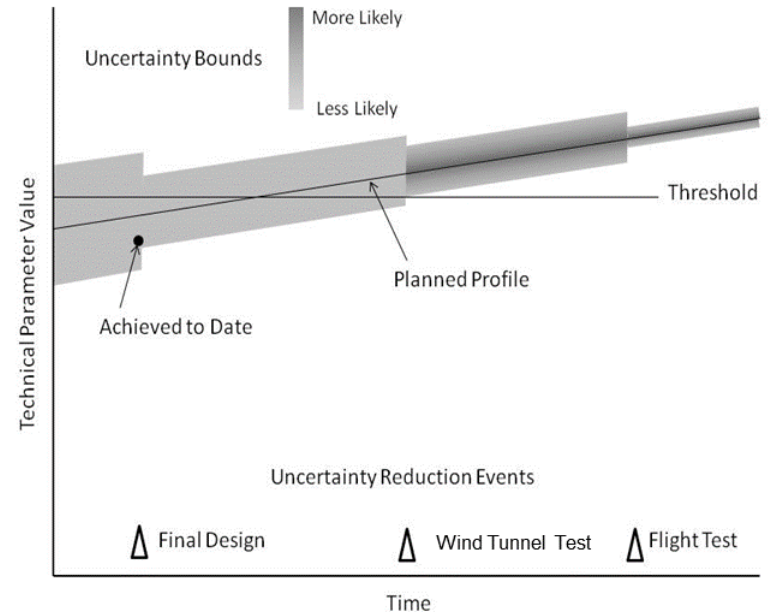
* SUD – System Under Development



MBSE and T&E

MBSE instantiation of the Digital Thread can improve test processes in several ways.

- First, enhanced communication can help test planners to better understand the system they are testing and influence the SEMP/TEMP processes
- Second, improved requirements definition and an emphasis on requirements traceability and testability can help test planners by providing clear test objectives with measurable outcomes
- MBSE can help to define an optimum test program by determining the information that is needed and the **acceptable uncertainty of the information derived from testing**
- MBSE approaches can use the system model, along with operational analysis, to establish uncertainty budgets for technical performance measures leading to **uncertainty goals for specific test events.**



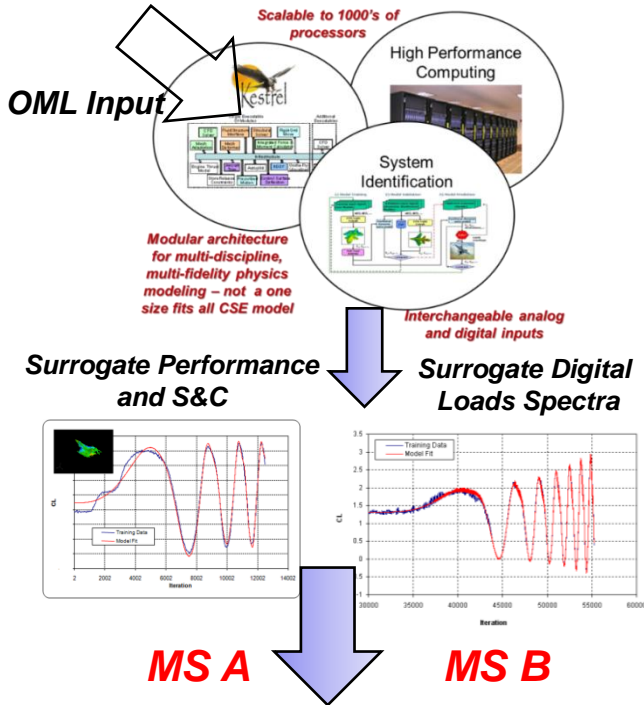
Eileen A. Bjorkman, Shahram Sarkani, Thomas A. Mazzuchi
“Using Model-Based Systems Engineering as a Framework for Improving Test and Evaluation Activities”

The Digital Thread is the communication architecture for an MBE/MBSE approach to lifecycle management



Digital Thread Approach to Aerodynamic Testing – Providing the Performance Baseline Truth

CREATE-AV



Requires a government/ industry enterprise approach to reducing total cycle time



Optimum GT Campaign

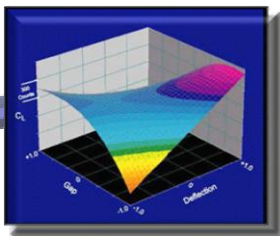
Merged Model, GT Data **CDR**



Optimum FT Campaign

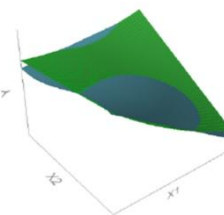
Merged Model, GT, FT Data **MS C**

Authoritative Digital Surrogate

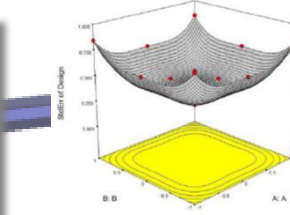


Modeled Truth

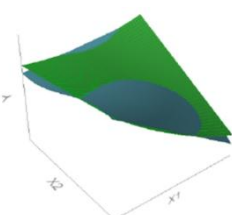
Quantified Margins and Uncertainties at Key Decision Points



Ground Truth



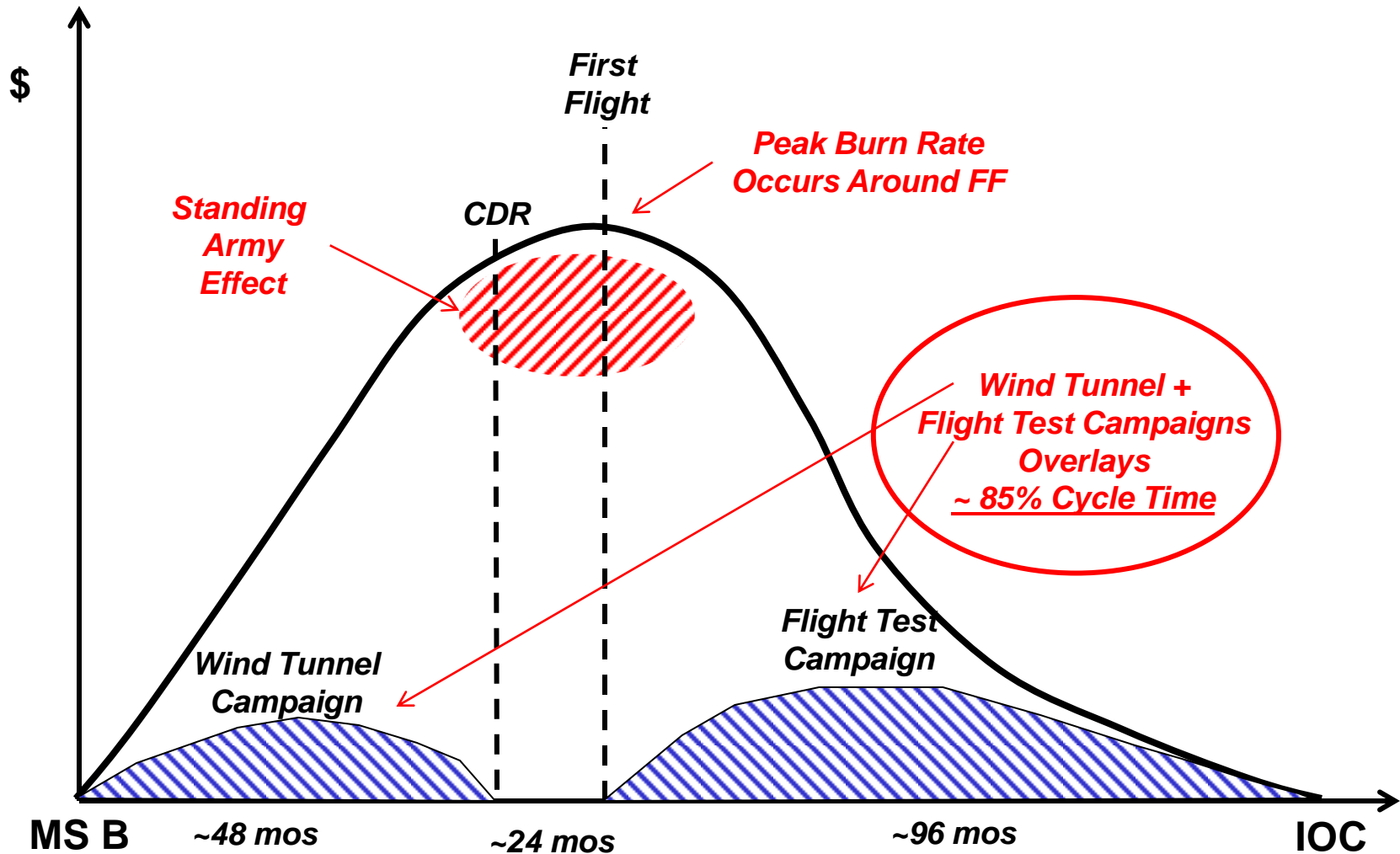
Quantified Margins and Uncertainties at Key Decision Points



Flight Truth

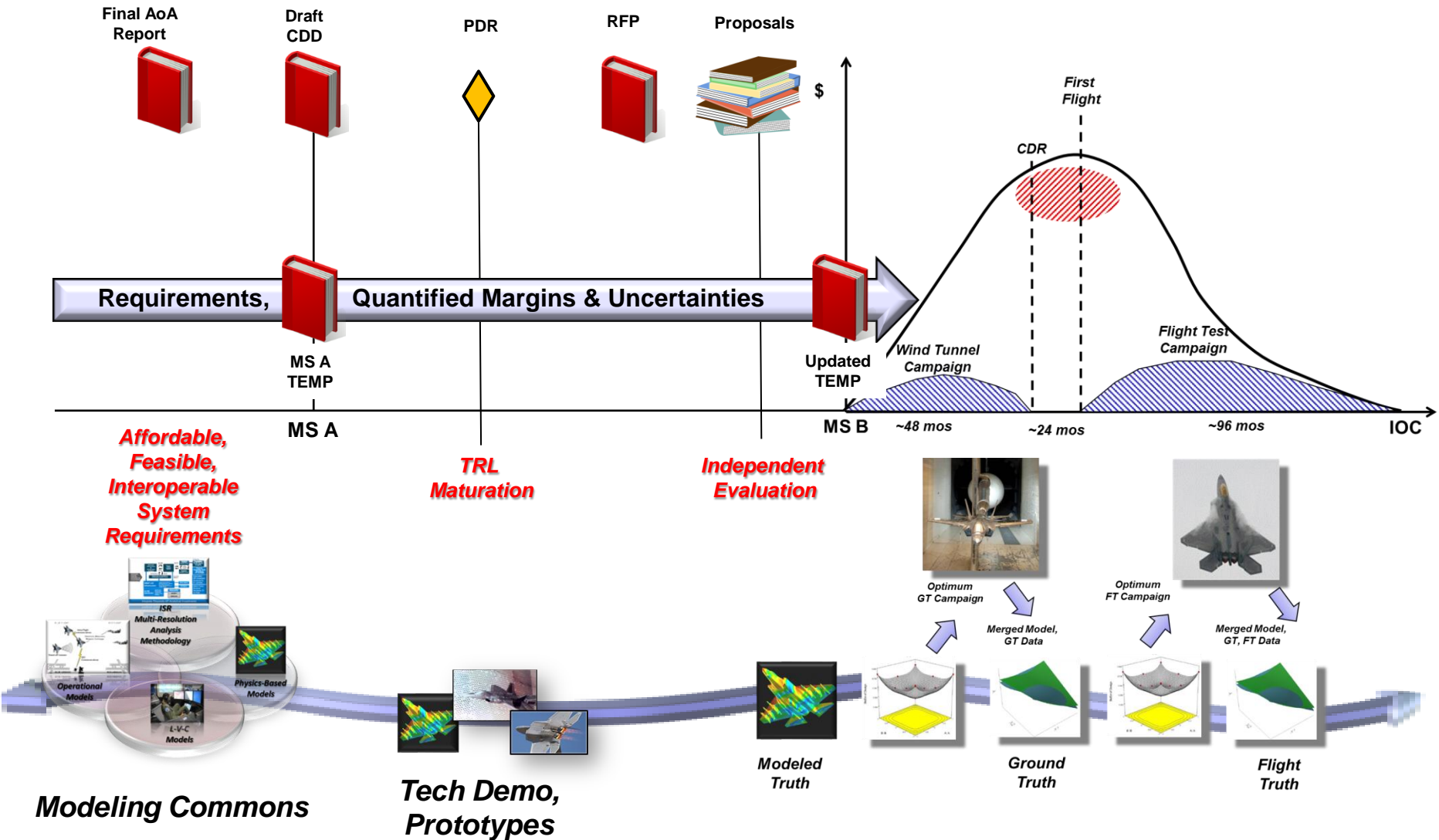


Anatomy of a Fixed-Wing Air Vehicle SDD Program





Starting at Milestone B is Late to Need



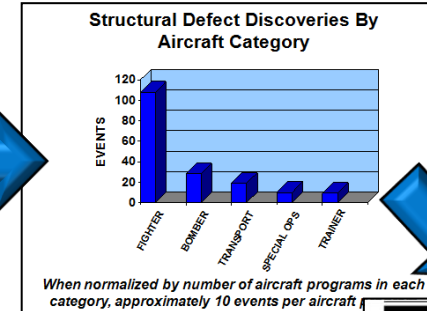
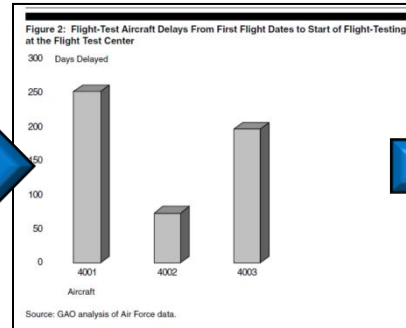
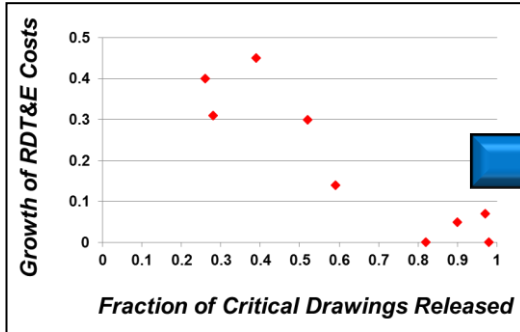


Value of a Quantified Digital Performance Evaluation Baseline

Close the Design at CDR...

Deliver FF Vehicle On Time...

Minimize Late Defects



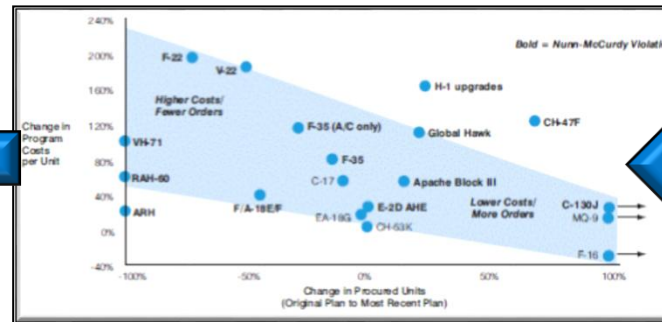
Minimize RDT&E Overruns

It All Starts with Quantified Performance Margins and Uncertainty Assessments at CDR

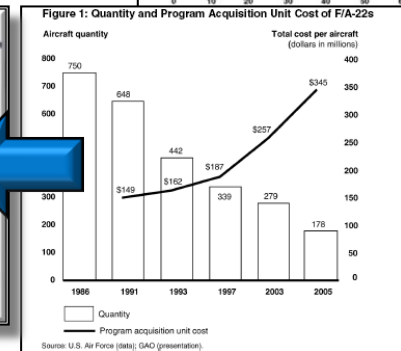
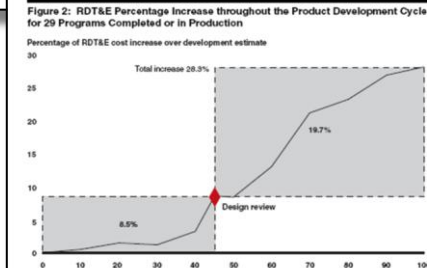


$$VALUE \equiv \frac{AIRCRAFT AVAILABLE}{PV(TOTAL OWNERSHIP COST)}$$

Maximize RDT&E Impact on Lifecycle Value



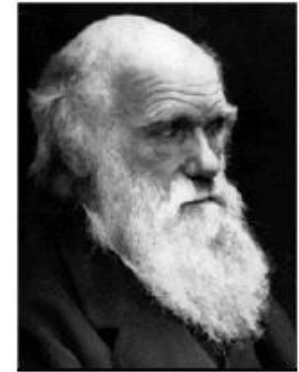
Deliver Contracted Number of Systems on Time/Cost





Summary

- The Digital Engineering revolution is underway across the Aerospace and Defense industry
- The T&E community needs to integrate Digital Engineering as a natural companion to testing
- The T&E community is best positioned to provide a quantified assessment of baseline performance in support of key decision points in the acquisition process, most notably the Critical Design Review
- Successful instantiation of Digital Engineering into the T&E environment will require
 - Policies to ensure T&E expertise is leveraged to provide the quantified baseline performance assessment
 - Very close collaboration between government and industry to improve processes leading to increase value from RDT&E



Charles Darwin 1809-1882

"It is not the strongest of the species that survive, nor the most intelligent, but the ones most adaptable to change"



Heads Up

Upcoming dialogues with industry on digital engineering and acquisition with emphasis on DT&E

- **Defense Planning And Analysis Society (DPAAS)
Dayton Ohio, November 17**
 - Luncheon overview of the Air Force Test Center
 - A Dialogue with Industry on Integrating Digital Engineering with Developmental T&E to Streamline Acquisition
- **SAF/AQ, NDIA, AIAA, AIA Industry Workshop
NDIA HQ Washington DC, November 28**
 - Digital Thread/Digital Twin Workshop with Industry

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